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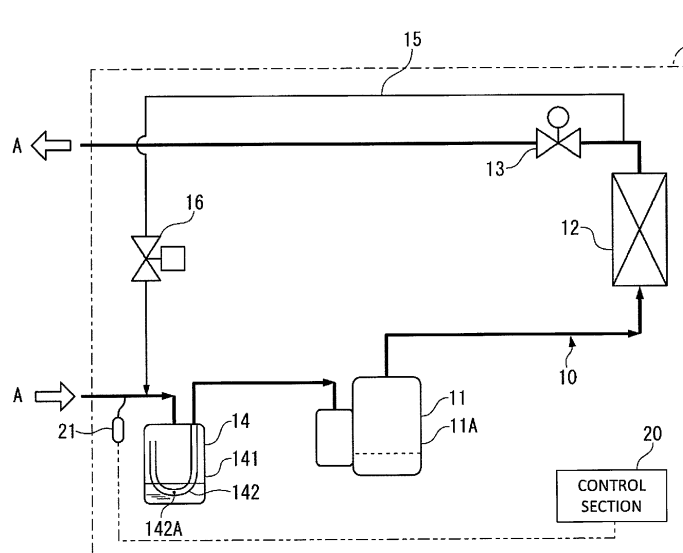
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(54) **REFRIGERATION UNIT, REFRIGERATION SYSTEM, AND METHOD OF CONTROLLING REFRIGERANT CIRCUIT**

(57) A refrigeration unit includes a gas-liquid separator (14), a bypass route (15) that causes at least a part of a refrigerant flowing toward a decompression section through a heat exchanger (12), to flow into the gas-liquid separator (14), a bypass valve (16) opening or closing the bypass route (15), and a control section (20) configured to control the bypass valve (16). The gas-liquid separator (14) includes an oil returning mechanism (142) that recovers refrigerating machine oil accumulated inside in a state of being dissolved in a liquid phase of the

refrigerant and returns the recovered refrigerating machine oil to a compressor (11). The control section (20) is configured to control the bypass valve (16) based on a predetermined condition under which deterioration of an oil returning property due to viscosity increase of the refrigerating machine oil is expected, to take bypass measures of opening the bypass route (15) or increasing a flow rate of the refrigerant flowing through the bypass route (15).

FIG. 1



Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a refrigeration unit configuring a refrigeration cycle, a refrigeration system including the refrigeration unit, and a method of controlling a refrigerant circuit.

Description of the Related Art

[0002] A refrigeration system such as a freezer and an air conditioner includes a heat source-side unit that includes a compressor and a condenser, and a heat utilization-side unit (such as freezer case and indoor air conditioner) that includes an evaporator. A refrigerant that has been discharged from the compressor of the heat source-side unit and condensed by the condenser flows out to the heat utilization-side unit, and is returned to the heat source-side unit through the evaporator.

[0003] The heat source-side unit (hereinafter, refrigeration unit) often includes a gas-liquid separator that separates a liquid refrigerant from the refrigerant to be sucked into the compressor in order to protect the compressor from liquid compression (e.g., JP 2010-210208 A and JP H5-79357 U).

[0004] In JP 2010-210208 A, to avoid deterioration of lubricity due to viscosity increase of refrigerating machine oil inside the compressor, a heater is provided on a casing of the compressor to prevent viscosity increase of the refrigerating machine oil.

[0005] The refrigerating machine oil used for lubrication of a sliding part of the compressor flows out to the heat utilization-side unit together with the refrigerant discharged from the compressor. To return the refrigerating machine oil to the compressor, the refrigerating machine oil that is accumulated, in a state of being dissolved in the liquid refrigerant, on a bottom inside the gas-liquid separator is sucked and recovered by an oil returning mechanism such as a U-shaped tube with a pickup hole and a capillary tube. The sucked refrigerating machine oil is returned to the compressor.

[0006] In JP H5-79357 U, in a case where discharge temperature of the refrigerant discharged from the compressor or suction temperature or a degree of superheat of the refrigerant to be sucked into the compressor becomes equal to or higher than a set value, a part of the liquid refrigerant condensed and liquefied by the condenser is sucked, together with gas refrigerant passed through the evaporator, into the compressor through the gas-liquid separator, which suppresses temperature increase of the gas refrigerant to be sucked into the compressor.

[0007] Prescribed refrigerant evaporation temperature is given to the refrigeration unit and the refrigeration system. Evaporation temperature is settable within a range

of the prescribed evaporation temperature.

[0008] When the evaporation temperature set according to the purpose of use of the refrigeration system and air temperature is such a low temperature that largely influences the viscosity of the refrigerating machine oil, the viscosity of the refrigerating machine oil that is accumulated, in a state of being dissolved in the liquid refrigerant, in the gas-liquid separator is increased, and suction of the refrigerating machine oil to the oil returning mechanism provided in the gas-liquid separator slows down. This deteriorates the return of the refrigerating machine oil from the gas-liquid separator to the compressor.

[0009] A hole diameter of the oil returning mechanism is designed such that a dilution rate of the refrigerating machine oil by the liquid refrigerant in the compressor becomes equal to or lower than an appropriate value at which lubricity is secured. If the hole diameter of the oil returning mechanism is increased in order to improve an oil returning property when the evaporation temperature is set to a low temperature at which the viscosity of the refrigerating machine oil is increased, the refrigerating machine oil is excessively returned, together with the liquid refrigerant, to the compressor when the viscosity is normal.

[0010] As with the above-described JP 2010-210208 A, the heater may be used to heat the gas-liquid separator, thereby preventing viscosity increase of the refrigerating machine oil. Additional installation of the heater, however, increases its manufacturing cost and running cost.

[0011] JP H5-79357 U described above relates to a phenomenon in which the refrigerating machine oil accumulated in the gas-liquid separator is not conveyed by the gas refrigerant to the compressor because the refrigerating machine oil is difficult to dissolve in the gas refrigerant when the temperature of the gas refrigerant to be sucked into the compressor is increased. JP H5-79357 U described above does not deal with the viscosity increase of the refrigerating machine oil when the evaporation temperature is set to a low temperature.

[0012] Therefore, an object of the present invention is to avoid deterioration of an oil returning property to the compressor due to viscosity increase of the refrigerating machine oil accumulated in the gas-liquid separator.

SUMMARY OF THE INVENTION

[0013] A refrigeration unit according to the present invention includes a refrigerant circuit including a compressor, a heat exchanger, and a decompression section and supplies, to a heat use destination, a refrigerant passed through the decompression section. The compressor compresses the refrigerant, the heat exchanger exchanges heat of the refrigerant with air, and the decompression section decompresses the refrigerant. The refrigeration unit includes a gas-liquid separator interposed between the heat use destination and the compressor, a bypass route configured to cause at least a part of the

refrigerant flowing toward the decompression section through the heat exchanger, to flow into the gas-liquid separator, a bypass valve configured to open or close the bypass route, or to regulate a flow rate of the refrigerant flowing through the bypass route, and a control section configured to control the bypass valve.

[0014] The gas-liquid separator includes an oil returning mechanism that recovers refrigerating machine oil accumulated inside in a state of being dissolved in a liquid phase of the refrigerant and returns the recovered refrigerating machine oil to the compressor.

[0015] Two-layer separation temperature on a low-temperature side of a mixed solution of the liquid phase of the refrigerant and the refrigerating machine oil is lower than a lower limit of prescribed evaporation temperature determined for the refrigeration unit.

[0016] The control section is configured to control the bypass valve based on a predetermined condition under which deterioration of an oil returning property due to viscosity increase of the refrigerating machine oil is expected, to take bypass measures of opening the bypass route or increasing the flow rate of the refrigerant flowing through the bypass route.

[0017] In the refrigeration unit according to the present invention, an index used for the condition is preferably saturation temperature corresponding to pressure of the refrigerant that is sucked into the compressor, and the control section is preferably configured to control the bypass valve to take the bypass measures in a case where the saturation temperature is lower than a prescribed value.

[0018] In the refrigeration unit according to the present invention, the control section is preferably configured to intermittently take the bypass measures every predetermined time based on the condition.

[0019] In the refrigeration unit according to the present invention, the control section is preferably configured to take the bypass measures in a case where saturation temperature corresponding to pressure of the refrigerant that is sucked into the compressor is lower than a prescribed value and a liquid level of the refrigerating machine oil in the compressor is lower than a prescribed liquid level.

[0020] In the refrigeration unit according to the present invention, the control section is preferably configured to control the bypass valve to terminate the bypass measures when a prescribed time elapses after the start of the bypass measures, or when the liquid level of the refrigerating machine oil in the compressor reaches at least the prescribed liquid level by the bypass measures.

[0021] In the refrigeration unit according to the present invention, the control section is preferably configured to take the bypass measures in a case where saturation temperature corresponding to pressure of the refrigerant that is sucked into the compressor is lower than a prescribed value and a degree of superheat of the refrigerating machine oil in the compressor is higher than a prescribed degree of superheat.

[0022] In the refrigeration unit according to the present invention, the control section is preferably configured to control the bypass valve to terminate the bypass measures when a prescribed time elapses after the start of the bypass measures, or when a degree of superheat of the refrigerating machine oil in the compressor is suppressed to at least a prescribed degree of superheat by the bypass measures.

[0023] A refrigeration system according to the present invention includes a compressor compressing a refrigerant, a heat exchanger exchanging heat of the refrigerant with air, a decompression section decompressing the refrigerant, and an evaporator evaporating the refrigerant. The refrigeration system includes a gas-liquid separator interposed between the evaporator and the compressor, a bypass route configured to cause at least a part of the refrigerant flowing toward the decompression section through the heat exchanger, to flow into the gas-liquid separator, a bypass valve configured to open or close the bypass route, or to regulate a flow rate of the refrigerant flowing through the bypass route, and a control section configured to control the bypass valve.

[0024] The gas-liquid separator includes an oil returning mechanism that recovers refrigerating machine oil accumulated inside in a state of being dissolved in a liquid phase of the refrigerant and returns the recovered refrigerating machine oil to the compressor.

[0025] Two-layer separation temperature on a low-temperature side of a mixed solution of the liquid phase of the refrigerant and the refrigerating machine oil is lower than a lower limit of prescribed evaporation temperature determined for the refrigeration system.

[0026] The control section is configured to control the bypass valve based on a predetermined condition under which deterioration of an oil returning property due to viscosity increase of the refrigerating machine oil is expected, to take bypass measures of opening the bypass route or increasing the flow rate of the refrigerant flowing through the bypass route.

[0027] Further, according to the present invention, there is provided a method of controlling a refrigerant circuit that includes a compressor compressing a refrigerant, a heat exchanger exchanging heat of the refrigerant with air, and a decompression section decompressing the refrigerant. The refrigerant circuit includes a gas-liquid separator, a bypass route, and a bypass valve. The gas-liquid separator is interposed between a heat use destination to which the refrigerant passed through the decompression section is supplied and the compressor. The bypass route causes at least a part of the refrigerant flowing toward the decompression section through the heat exchanger, to flow into the gas-liquid separator. The bypass valve opens or closes the bypass route, or regulates a flow rate of the refrigerant flowing through the bypass route. The method includes controlling the bypass valve to open the bypass route or to increase the flow rate of the refrigerant flowing through the bypass route, based on a predetermined condition under which

deterioration of an oil returning property due to viscosity increase of refrigerating machine oil is expected, and causing an oil returning mechanism provided in the gas-liquid separator to recover the refrigerating machine oil accumulated, in a state of being dissolved in a liquid phase of the refrigerant, inside the gas-liquid separator, and to return the recovered refrigerating machine oil to the compressor.

[0028] According to the present invention, an appropriate amount of liquid phase of the refrigerant is mixed, through the bypass route, to the refrigerating machine oil accumulated in the gas-liquid separator at a suitable time, based on the condition under which deterioration of the oil returning property due to viscosity increase of the refrigerating machine oil in the gas-liquid separator is expected. Accordingly, viscosity increase of the entire mixed solution of the refrigerating machine oil accumulated in the gas-liquid separator and the liquid refrigerant is suppressed even at a low temperature. Therefore, it is possible to recover the refrigerating machine oil accumulated in the gas-liquid separator by an amount sufficient as the mixed solution and to return the recovered refrigerating machine oil to the compressor by the oil returning mechanism also when the evaporation temperature is set to a low temperature while maintaining an appropriate dilution rate of the refrigerating machine oil in the compressor and a role of liquid compression by the gas-liquid separator without additionally installing a heater in the gas-liquid separator.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029]

FIG. 1 is a schematic diagram illustrating a refrigeration unit according to a first embodiment;
FIG. 2 is a schematic diagram illustrating a refrigeration unit according to a second embodiment; and
FIG. 3 is a schematic diagram illustrating a refrigeration unit according to a third embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] Some embodiments of the present invention are described below with reference to accompanying drawings.

[First Embodiment]

[0031] A refrigeration unit 1 (condensing unit) illustrated in FIG. 1 includes a heat source circuit 10, a gas-liquid separator 14, a bypass route 15, a bypass valve 16, and a control section 20. The heat source circuit 10 includes a compressor 11, a heat exchanger 12, and a decompression section 13. A housing that houses the components 11 to 13 of the heat source circuit 10, the gas-liquid separator 14, the bypass route 15, and the bypass valve

16 is disposed outdoors.

[0032] The refrigeration unit 1 exchanges, by the heat exchanger 12, heat of a refrigerant compressed by the compressor 11 with air as a heat source, then decompresses the refrigerant by the decompression section 13 such as an expansion valve, and supplies the refrigerant passed through the decompression section 13, to a heat use destination A disposed indoors.

[0033] The heat use destination A includes an unillustrated evaporator that configures a refrigeration cycle, together with the heat source circuit 10 of the refrigeration unit 1. The refrigeration system includes an unillustrated heat use destination unit provided with the evaporator, the refrigeration unit 1, and piping that connects the heat use destination unit and the refrigeration unit 1. The heat use destination unit corresponds to, for example, a refrigerator case and a freezer case that are installed in a store and house foods.

[0034] Prescribed refrigerant evaporation temperature is given to the refrigeration unit 1. Evaporation temperature is settable within a range of the prescribed evaporation temperature.

[0035] An appropriate refrigerant, for example, an HFC refrigerant such as R404A, and a natural refrigerant such as CO₂ are usable for the refrigeration system according to the present embodiment.

[0036] The refrigerant that has been discharged from the compressor 11 and heat-exchanged with the outside air by the heat exchanger 12 flows out to the heat use destination A, and is returned to the refrigeration unit 1 through the evaporator of the heat use destination A.

[0037] The refrigeration system according to the present embodiment is applicable to any of a subcritical cycle and a transcritical cycle. The heat exchanger 12 functions as a condenser that condenses and liquefies an inflow gas refrigerant through heat exchange with the air, in the subcritical cycle. In contrast, in the transcritical cycle that uses, for example, a CO₂ refrigerant, the heat exchanger 12 functions as a gas cooler that cools an inflow refrigerant in a supercritical state through heat exchange with the air.

[0038] Refrigerating machine oil is sealed in a housing 11A of the compressor 11 in order to lubricate a sliding part such as a bearing of a built-in compression mechanism. As the refrigerating machine oil, oil having compatibility with the refrigerant used in the refrigeration system according to the present embodiment is appropriately selectable. In terms of the compatibility, for example, ester synthetic oil is selectable for CO₂. Examples of the selectable ester synthetic oil include "diamond freeze MA68" that is a product available from JXTG Nippon Oil & Energy Corporation. With respect to R404A that is one kind of HFC refrigerant, "diamond freeze MA32R" that is a product available from JXTG Nippon Oil & Energy Corporation is selectable.

[0039] The refrigerating machine oil dissolves in the refrigerant. Therefore, the refrigerating machine oil is discharged together with the refrigerant from the compres-

sor 11, and flows out to the heat use destination A through the heat exchanger 12 and the decompression section 13.

[0040] The present embodiment includes main features in the configuration of the refrigerant circuit that includes the heat source circuit 10, the gas-liquid separator 14, the bypass route 15, and the bypass valve 16, and in a method of controlling the refrigerant circuit by the control section 20.

[0041] The refrigerant to be sucked into the compressor 11 is received by the gas-liquid separator 14 interposed between the heat use destination A and the compressor 11 and is separated into a gas refrigerant and a liquid refrigerant in order to protect the compressor 11 from liquid compression.

[0042] The gas-liquid separator 14 (accumulator) includes a tank 141 and an oil returning mechanism 142. The tank 141 receives the refrigerant returned from the heat use destination A. The oil returning mechanism 142 recovers the refrigerating machine oil that is accumulated, in a state of being dissolved with the liquid refrigerant, on a bottom inside the tank 141 and returns the recovered refrigerating machine oil to the compressor 11.

[0043] Since the liquid refrigerant is accumulated on the bottom inside the tank 141, the gas refrigerant is sucked into the compressor 11 from an upper part inside the tank 141.

[0044] The oil returning mechanism 142 includes, for example, a U-shaped tube with a pickup hole 142A (small hole) or a capillary tube.

[0045] The refrigerating machine oil accumulated inside the tank 141 is sucked by the oil returning mechanism 142, and is sucked together with the gas refrigerant into the compressor 11 to be returned to the inside of the housing 11A of the compressor 11. The refrigerating machine oil is accumulated, in the state of being dissolved in the liquid refrigerant, also in the housing 11A of the compressor 11.

[0046] A hole diameter of the oil returning mechanism 142 is designed such that a dilution rate of the refrigerating machine oil by the liquid refrigerant in the compressor 11 becomes equal to or lower than an appropriate value at which lubricity is secured.

[0047] The refrigerating machine oil is increased in viscosity due to temperature decrease. Accordingly, if the refrigerant evaporation temperature is such a low temperature that largely influences the viscosity of the refrigerating machine oil, deterioration of an oil returning property of the refrigerating machine oil accumulated in the gas-liquid separator 14, to the compressor 11 is expected. The evaporation temperature corresponds to outlet temperature of the evaporator in the heat use destination unit.

[0048] The evaporation temperature of the refrigeration unit 1 is determined in a range of, for example, -5°C to -45°C . This temperature range is referred to as the prescribed evaporation temperature. The optional evaporation temperature is settable within the range of the

prescribed evaporation temperature by the user according to use application of the refrigeration system including the refrigeration unit 1, air temperature, etc. The evaporation temperature set by the user is referred to as set evaporation temperature.

[0049] When the viscosity of the refrigerating machine oil is increased and suction of the refrigerating machine oil to the oil returning mechanism 142 slows down, return of the refrigerating machine oil from the gas-liquid separator 14 to the compressor 11 is deteriorated.

[0050] To avoid deterioration of the oil returning property from the gas-liquid separator 14 to the compressor 11 due to viscosity increase of the refrigerating machine oil, the refrigeration unit 1 according to the present embodiment mixes the liquid refrigerant to the gas-liquid separator 14 through the bypass route 15 at a suitable time, thereby suppressing viscosity increase of a mixed solution of the refrigerating machine oil accumulated in the gas-liquid separator 14 and the liquid refrigerant.

[0051] Accordingly, the refrigeration unit 1 includes the bypass route 15 that causes a part of the refrigerant passed through the heat exchanger 12 to flow into the gas-liquid separator 14 and the bypass valve 16 that opens or closes the bypass route 15, as well as controls, by the control section 20, the bypass valve 16 based on a predetermined condition under which deterioration of the oil returning property due to viscosity increase of the refrigerating machine oil in the gas-liquid separator 14 is expected. To obtain suction pressure saturation temperature as an index used for the condition under which deterioration of the oil returning property is expected, a pressure sensor 21 that detects pressure of the refrigerant sucked into the compressor 11 is used in the present embodiment. The suction pressure saturation temperature varies according to the set evaporation temperature.

[0052] The bypass route 15 includes piping that connects an outlet side of the heat exchanger 12 and an inlet side of the gas-liquid separator 14, and a fitting, etc.

[0053] The bypass valve 16 is a solenoid valve that is driven in response to an instruction issued from the control section 20 to open or close the bypass route 15. When the bypass route 15 is opened by the bypass valve 16, a part of the refrigerant that flows toward the decompression section 13 through the heat exchanger 12, flows into the gas-liquid separator 14 through the bypass route 15. The refrigerant that has flowed through the bypass route 15 and reached the gas-liquid separator 14 is decompressed into a gas-liquid two-phase state.

[0054] The refrigerant that has passed through the evaporator of the heat use destination A and the refrigerant that has flowed through the bypass route 15 flow into the gas-liquid separator 14. The refrigerant that has flowed into the tank 141 of the gas-liquid separator 14 is separated into gas phase and liquid phase due to density difference, and the liquid phase having density larger than density of the gas phase is accumulated on the bottom of the tank 141.

[0055] As described above, the refrigerating machine

oil in the state of being dissolved in the refrigerant is also conveyed through the refrigerant circuit together with the refrigerant. Therefore, the refrigerating machine oil included in each of the refrigerant from the heat use destination A and the refrigerant from the bypass route 15 also flows into the gas-liquid separator 14, and is accumulated on the bottom of the tank 141. The refrigerating machine oil is mixed with the liquid refrigerant on the bottom of the tank 141 and dissolves in the liquid refrigerant.

[0056] In the present embodiment, the refrigerant that has flowed through the bypass route 15 is merged with the refrigerant that flows toward the gas-liquid separator 14 from the heat use destination A, and the merged refrigerant flows into the gas-liquid separator 14. The configuration is not limited thereto, and the refrigerant that has flowed through the bypass route 15 may not be merged with the flow of the refrigerant from the heat use destination A, and may directly flow into the gas-liquid separator 14.

[0057] In a case where deterioration of the oil return property due to viscosity increase of the refrigerating machine oil is expected, the control section 20 transmits, to the bypass valve 16, an instruction to open the bypass route 15, thereby opening the bypass route 15. Thus, bypass measures are started.

[0058] In the present embodiment, the control section 20 uses suction pressure detected by the pressure sensor 21, to calculate saturation temperature corresponding to the suction pressure. In a case where the suction pressure saturation temperature in the gas-liquid separator 14 is lower than the prescribed value, the control section 20 transmits the instruction to the bypass valve 16 to open the bypass route 15, and causes the refrigerant to flow into the gas-liquid separator 14 through the bypass route 15 because deterioration of the oil returning property is expected.

[0059] The pressure sensor 21 is installed on the inlet side of the gas-liquid separator 14 in the present embodiment; however, the pressure sensor 21 may be installed at an appropriate position at which the pressure sensor 21 can detect pressure serving as a representative of the pressure of the refrigerant sucked into the compressor 11. For example, the pressure sensor 21 may be installed at a position between the gas-liquid separator 14 and the compressor 11 or near a terminal of the bypass route 15.

[0060] When the liquid phase of the refrigerant with the gas-liquid two-phase that has flowed into the gas-liquid separator 14 through the bypass route 15, is mixed to the mixed solution accumulated in the tank 141, the ratio of the liquid refrigerant in the mixed solution is increased.

[0061] Accordingly, mixing of the liquid phase of the refrigerant through the bypass route 15 suppresses the viscosity increase of the entire mixed solution of the refrigerating machine oil accumulated in the gas-liquid separator 14 and the liquid refrigerant even at a low temperature near a lower limit of the prescribed evaporation temperature. Accordingly, it is possible to recover and

return the refrigerating machine oil accumulated in the tank 141 by an amount sufficient as the mixed solution, to the compressor 11 by the oil returning mechanism 142. This makes it possible to prevent poor lubrication and seizure in the compressor 11.

[0062] The bypass measures that mix the liquid refrigerant to the refrigerating machine oil in the gas-liquid separator 14 through the bypass route 15 are taken only for a prescribed time in a case where the suction pressure saturation temperature is lower than the prescribed value. The conditions of the specific temperature and time for implementation may be appropriately determined.

[0063] The bypass measures according to the present embodiment are based on the fact that mixing the liquid phase of the refrigerant to the refrigerating machine oil inside the gas-liquid separator 14 through the bypass route 15 reduces concentration of the refrigerating machine oil in the mixed solution inside the gas-liquid separator 14. According to such bypass measures, it is possible to suppress viscosity increase of the entire mixed solution also under the temperature condition at which the viscosity of the single refrigerating machine oil is increased.

[0064] A state where the liquid refrigerant and the refrigerating machine oil do not dissolve each other and are separated into two layers or a state where the liquid refrigerant and the refrigerating machine oil are emulsified is referred to as two-layer separation, and the temperature causing such a state is referred to as two-layer separation temperature.

[0065] The two-layer separation temperature of the refrigerating machine oil and the liquid refrigerant is represented by a two-layer separation temperature curve indicating relationship between the concentration and the temperature of the refrigerating machine oil. The two-layer separation temperature curve includes a two-layer separation temperature curve (curve with downward convex) on a high-temperature side in which the separation is started as the temperature is increased, and a two-layer separation temperature curve (curve with upward convex) on a low-temperature side in which the separation is started as the temperature is decreased.

[0066] The mixed solution of the liquid refrigerant and the refrigerating machine oil is separated from one phase with a uniform concentration into two phases with different concentrations at a temperature lower than the two-layer separation temperature curve on the low-temperature side.

[0067] To suppress viscosity increase of the entire mixed solution of the liquid phase of the refrigerant and the refrigerating machine oil and to sufficiently secure the oil returning property as described above, the refrigerating machine oil is uniformly dissolved into the liquid refrigerant without separation of the mixed solution. Therefore, the refrigerant and the refrigerating machine oil are selected such that two-layer separation temperature on the low-temperature side that is the maximum value of the two-layer separation temperature curve on

the low-temperature side (upper critical solution temperature: UCST) becomes lower than a lower limit of the prescribed evaporation temperature determined for the refrigeration unit. The two-layer separation temperature on the low-temperature side is preferably lower than the lower limit of the prescribed evaporation temperature by, for example, 10°C or higher with an extra margin. For example, in a case where the lower limit of the prescribed evaporation temperature is -45°C, a combination of the refrigerant and the refrigerating machine oil that causes the two-layer separation temperature on the low-temperature side to be equal to or lower than -55°C is preferably adopted. Examples of the combination causing the two-layer separation temperature on the low-temperature side to be equal to or lower than -55°C include a combination of a CO₂ refrigerant and the diamond freeze MA68 described above.

[0068] An example of the implementation condition of the bypass measures is described below.

[0069] The control section 20 takes the bypass measures of opening the bypass route 15 for five minutes as the prescribed time from the start of the bypass measures every time an integrated operation time of the refrigeration unit 1 reaches 60 minutes and the suction pressure saturation temperature is equal to or lower than -30°C as the prescribed value while monitoring the suction pressure saturation temperature that is calculated with use of the pressure detected by the pressure sensor 21. In other words, the bypass measures are intermittently taken every 60 minutes during operation of the refrigeration system including the refrigeration unit 1 when the evaporation temperature is set to a low temperature. This smoothly returns the refrigerating machine oil accumulated in the gas-liquid separator 14, to the compressor 11 without delay of the oil return to the compressor 11.

[0070] In the refrigeration unit 1, for example, the set evaporation temperature is variable within the wide range of the prescribed evaporation temperature of -5°C to -45°C. Therefore, although the set evaporation temperature largely influences the viscosity of the refrigerating machine oil and the oil returning property from the gas-liquid separator 14 in the low temperature range of the prescribed evaporation temperature, the refrigerating machine oil has appropriate viscosity sufficiently recoverable by the oil returning mechanism 142 and the set evaporation temperature does not influence the oil returning property in the other temperature range in some cases.

[0071] If the diameter of the pickup hole 142A of the oil returning mechanism 142 or the diameter of the capillary tube used in the oil returning mechanism is increased in order to recover the sufficient amount of the refrigerating machine oil from the inside of the tank 141 to the oil returning mechanism 142 when the viscosity of the refrigerating machine oil is increased and the evaporation temperature is set to a low temperature, the liquid is excessively returned by the oil returning mechanism 142 from the gas-liquid separator 14 to the compressor

11 when the temperature is set in the other temperature range. To protect the compressor 11 from the liquid compression and to obtain sufficient lubricity by the refrigerating machine oil diluted with the liquid refrigerant, it is necessary to return an appropriate amount of the refrigerating machine oil accumulated in the gas-liquid separator 14 to the compressor 11.

[0072] In addition, the lower part of the tank 141 of the gas-liquid separator 14 may be heated by a heater in order to prevent viscosity of the refrigerating machine oil in the gas-liquid separator 14 from being increased also when the evaporation temperature is set to a low temperature. Additional installation of the heater, however, increases the manufacturing cost of the refrigeration unit 1 including a controller of the heater and the running cost.

[0073] According to the present embodiment, the liquid phase of the refrigerant is mixed, through the bypass route 15, to the refrigerating machine oil accumulated in the gas-liquid separator 14, based on the condition under which deterioration of the oil returning property due to viscosity increase of the refrigerating machine oil in the gas-liquid separator 14 is expected. This makes it possible to smoothly return an appropriate amount of the refrigerating machine oil to the compressor 11 also when the evaporation temperature is set to a low temperature while maintaining the appropriate dilution rate of the refrigerating machine oil in the compressor 11 and the role of the liquid compression by the gas-liquid separator 14, without additional installation of a heater in the gas-liquid separator 14.

[Second Embodiment]

[0074] Next, a second embodiment of the present invention is described.

[0075] In the following, matters different from the first embodiment are mainly described. Components similar to those in the first embodiment are denoted by the same reference numerals. It is true of a third embodiment described later.

[0076] A refrigeration unit 2 according to the second embodiment illustrated in FIG. 2 includes a refrigerant circuit that has a configuration similar to that of the refrigeration unit 1 according to the first embodiment, a control section 22, the pressure sensor 21, and an oil level sensor 23.

[0077] The oil level sensor 23 detects a liquid level (oil level) of the refrigerating machine oil accumulated, in the state of being dissolved in the liquid refrigerant, inside the housing 11A of the compressor 11. The oil level is used as an index of returning situation of the refrigerating machine oil to the compressor 11.

[0078] When the bypass route 15 is open, the flow rate of the refrigerant flowing into the heat use destination A is decreased and the flow rate of the refrigerant circulating the entire refrigerant circuit is decreased because a part of the refrigerant passed through the heat exchanger 12 flows into the bypass route 15. Accordingly, refriger-

ating capacity is deteriorated. In consideration thereof, in the present embodiment, the bypass route 15 is opened or closed based on a condition relating to the detected liquid level of the refrigerating machine oil in the compressor 11 in addition to the suction pressure saturation temperature.

[0079] An example of control using the pressure sensor 21 and the oil level sensor 23 is described below.

[0080] In the control, the oil level sensor 23 includes a first oil level switch 231 and a second oil level switch 232. The first oil level switch 231 detects that the liquid level of the refrigerating machine oil accumulated in the compressor 11 becomes lower than a prescribed first liquid level. The second oil level switch 232 detects that the liquid level of the refrigerating machine oil accumulated in the compressor 11 becomes higher than a prescribed second liquid level higher than the first liquid level. The first oil level switch 231 and the second oil level switch 232 are turned on or off according to the corresponding liquid level, respectively.

[0081] In this example, to avoid hunting that causes frequent repetition of the bypass measures, two liquid levels (first liquid level and second liquid level) as prescribed liquid levels are used in the control. The control according to the bypass measures, however, may be performed with use of only one prescribed liquid level. In this case, it is sufficient to provide only one oil level switch.

[0082] When the first oil level switch 231 is turned on (or off) because the suction pressure saturation temperature that has been calculated by the control section 22 with use of the pressure detected by the pressure sensor 21 is set to the prescribed value or lower, namely, the evaporation temperature of the refrigeration unit 2 is set to a low temperature and the liquid level of the refrigerating machine oil in the compressor 11 becomes lower than the first liquid level, the bypass valve 16 is controlled by the control section 22 and the bypass route 15 is accordingly opened. As a result, the bypass measures are started.

[0083] The liquid phase of the refrigerant that has flowed into the gas-liquid separator 14 through the bypass route 15 is mixed to the refrigerating machine oil accumulated in the gas-liquid separator 14, which improves an oil returning property. Accordingly, the refrigerating machine oil of an amount sufficient to prevent poor lubrication and seizure is returned to the compressor 11.

[0084] Thereafter, when the liquid level of the refrigerating machine oil accumulated in the compressor 11 reaches the second liquid level and the second oil level switch 232 is turned on (or off), the bypass valve 16 is controlled by the control section 22 and the bypass route 15 is accordingly closed.

[0085] To prevent excessive progression of dilution of the refrigerating machine oil by the liquid phase of the refrigerant that has flowed into the gas-liquid separator 14 through the bypass route 15, the bypass route 15 is preferably closed to terminate the bypass measures and

to inhibit further progression of dilution at a time when the liquid level of the refrigerating machine oil in the compressor 11 reaches at least the first liquid level, preferably the second liquid level and improvement of the oil returning property becomes unnecessary any more.

[0086] According to the second embodiment, it is possible to limitedly take the bypass measures only in a case where improvement of the oil returning property is necessary because the oil returning property is deteriorating, based on the actual oil returning situation detectable by the oil level sensor 23. Therefore, it is possible to prevent poor lubrication and seizure in the compressor 11 while suppressing deterioration of refrigerating capacity.

[0087] The control in the above-described second embodiment may be modified in the following manner.

[0088] For example, the control section 22 may be configured to control the bypass valve 16 to open the bypass route 15 only in a case where the liquid level of the refrigerating machine oil accumulated in the compressor 11 is lower than the prescribed liquid level every time the integrated operation time of the refrigeration unit 2 reaches 60 minutes and the suction pressure saturation temperature is equal to or lower than -30°C as the prescribed value.

[0089] Thereafter, when the liquid level of the refrigerating machine oil in the compressor 11 reaches at least the prescribed liquid level or, for example, five minutes elapse as the prescribed time after the bypass measures of opening the bypass route 15 are started, the bypass valve 16 is controlled and the bypass route 15 is closed to terminate the bypass measures.

[Third Embodiment]

[0090] Next, a third embodiment of the present invention is described.

[0091] A refrigeration unit 3 according to the third embodiment illustrated in FIG. 3 includes a refrigerant circuit including a configuration similar to that of the refrigeration unit 1 of the first embodiment, a control section 24, the pressure sensor 21, and a temperature sensor 25.

[0092] In the present embodiment, the temperature of the refrigerating machine oil in the compressor 11 or temperature allowing for estimation of the temperature of the refrigerating machine oil in the compressor 11 is used in control. The temperature sensor 25 is disposed on a lower outer periphery of the housing 11A in order to detect the temperature of the refrigerating machine oil accumulated in the housing 11A of the compressor 11.

[0093] The control section 24 calculates a degree of superheat of the refrigerating machine oil (hereinafter, degree of oil superheat) from a difference between the temperature detected by the temperature sensor 25 and the suction pressure saturation temperature detected by the pressure sensor 21. The degree of oil superheat is used as an index of the returning situation of the refrigerating machine oil to the compressor 11.

[0094] In a case where the pressure inside the housing

11A of the compressor 11 is set to high pressure like a CO₂ refrigerant, the degree of oil superheat is calculated from a difference between the saturation temperature corresponding to discharge pressure and one of the temperature and the estimated temperature of the refrigerating machine oil in the compressor 11. In this case, the saturation temperature is calculated from the discharge pressure detected by a pressure sensor that is installed on the discharge side of the compressor 11.

[0095] Also in the present embodiment, the bypass measures are taken only in the case where improvement of the oil returning property is required based on the degree of oil superheat in considering the refrigerating capacity.

[0096] An example of control using the suction pressure saturation temperature and the degree of oil superheat is described below. In the control, it is assumed that a first degree of superheat and a second degree of superheat lower than the first degree of superheat are set for the degree of oil superheat of the compressor 11. The first degree of superheat indicates that the oil returning property is deteriorating.

[0097] Also in the present embodiment, the two degrees of superheat (first degree of superheat and second degree of superheat) as the prescribed degrees of superheat are used in the control in order to avoid hunting. The control according to the bypass measures, however, may be performed with use of only one prescribed degree of superheat.

[0098] When the suction pressure saturation temperature that has been calculated by the control section 24 with use of the pressure detected by the pressure sensor 21 is equal to or lower than the prescribed value and the degree of oil superheat in the compressor 11 is higher than the first degree of superheat, the bypass valve 16 is controlled by the control section 24 and the bypass route 15 is accordingly opened.

[0099] When the degree of oil superheat in the compressor 11 is suppressed to the second degree of superheat by the above-described bypass measures, the bypass valve 16 is controlled by the control section 24 and the bypass route 15 is accordingly closed.

[0100] When the degree of oil superheat is suppressed to at least the first degree of superheat, preferably the second degree of superheat, the mixed solution of the refrigerating machine oil and the liquid refrigerant of an amount sufficient for lubrication is accumulated in the compressor 11. Therefore, the bypass route 15 is preferably closed to inhibit further progression of dilution.

[0101] According to the third embodiment, it is possible to limitedly take the bypass measures only in the case where improvement of the oil returning property is necessary based on the degree of oil superheat allowing for estimation of an amount of the refrigerating machine oil dissolved in the liquid refrigerant inside the compressor 11. Therefore, it is possible to prevent poor lubrication and seizure in the compressor 11 while suppressing deterioration of refrigerating capacity.

[0102] The control in the above-described third embodiment may be modified in the following manner.

[0103] For example, the control section 24 may be configured to control the bypass valve 16 to open the bypass route 15 only in a case where the degree of superheat of the refrigerating machine oil accumulated in the compressor 11 is higher than the prescribed degree of superheat every time the integrated operation time of the refrigeration unit 3 reaches 60 minutes and the suction pressure saturation temperature is equal to or lower than -30°C as the prescribed value.

[0104] Thereafter, when the degree of superheat of the refrigerating machine oil in the compressor 11 is suppressed to at least the prescribed degree of superheat or, for example, five minutes elapse after the bypass measures of opening the bypass route 15 are started, the bypass valve 16 is controlled and the bypass route 15 is closed to terminate the bypass measures.

[0105] Different indices may be used for the start condition of the bypass measures and for the termination condition of the bypass measures. For example, control may be performed to start the bypass measures when the liquid level of the refrigerating machine oil in the compressor 11 becomes lower than the prescribed liquid level, and to terminate the bypass measures when the prescribed time elapses after the start of the bypass measures or the degree of superheat of the refrigerating machine oil in the compressor 11 is suppressed by the bypass measures to at least the prescribed degree of superheat.

[0106] Other than the above, the configurations described in the above-described embodiments may be selected or appropriately modified without departing from the scope of the present invention.

[0107] Application of the present invention is not limited to the refrigeration system including a refrigerator/freezer case and the condensing unit configuring the system. The present invention is applicable to a refrigeration system relating to an air conditioner, a container, and the like, and a refrigeration unit configuring the system.

[0108] The bypass valve 16 is not necessarily a switching valve, and may be configured as a flow rate regulation valve that regulates the flow rate of the refrigerant flowing through the bypass route 15.

[0109] In this case, for example, the following control becomes possible.

[0110] Even if the evaporation temperature is not set to such a low temperature that largely influences the viscosity of the refrigerating machine oil, the control section 20 is configured to control an opening degree of the bypass valve 16 such that a small amount of refrigerant flows through the bypass route 15. Further, when the evaporation temperature is set to a low temperature, the control section 20 is configured to controls the bypass valve 16 so as to increase the flow rate of the refrigerant flowing through the bypass route 15, based on the condition under which deterioration of the oil returning property from the gas-liquid separator 14 to the compressor

11 is expected. This increases the amount of the liquid refrigerant mixed, through the bypass route 15, to the mixed solution accumulated in the gas-liquid separator 14, and the concentration of the refrigerating machine oil in the mixed solution is accordingly decreased. Therefore, it is possible to suppress viscosity increase of the entire mixed solution returned to the compressor 11 and to avoid deterioration of the oil returning property.

[0111] The bypass measures of increasing the flow rate of the refrigerant flowing through the bypass route 15 are preferably taken intermittently every predetermined time, or are preferably taken only in a case where improvement of the oil returning property is necessary according to the returning situation of the refrigerating machine oil indicated by the liquid level or the degree of superheat of the refrigerating machine oil in the compressor 11.

[0112] The flow rate of the refrigerant flowing through the bypass route 15 is preferably reduced through the control of the bypass valve 16 when a predetermined time elapses after the flow rate of the refrigerant to be bypassed is increased or necessity of the bypassing is eliminated from the oil returning situation.

[0113] In each of the above-described embodiments, only a part of the refrigerant that flows toward the decompression section 13 through the heat exchanger 12 is caused to flow into the gas-liquid separator 14 through the bypass route 15. If it is necessary to immediately improve the oil returning property, however, all of the refrigerant that flows toward the decompression section 13 through the heat exchanger 12 may be caused to flow into the gas-liquid separator 14 through the bypass route 15. In this case, the bypass valve 16 may be provided at, for example, a start end of the bypass route 15 branched from a main stream on the outlet side of the heat exchanger 12.

Claims

1. A refrigeration unit that includes a refrigerant circuit (10) including a compressor (11), a heat exchanger (12), and a decompression section (13) and is configured to supply, to a heat use destination (A), a refrigerant passed through the decompression section (13), the compressor (11) compressing the refrigerant, the heat exchanger (12) exchanging heat of the refrigerant with air, and the decompression section (13) decompressing the refrigerant, the refrigeration unit comprising:

a gas-liquid separator (14) interposed between the heat use destination (A) and the compressor (11);

a bypass route (15) configured to cause at least a part of the refrigerant flowing toward the decompression section (13) through the heat exchanger (12), to flow into the gas-liquid separator (14);

tor (14);

a bypass valve (16) configured to open or close the bypass route (15), or to regulate a flow rate of the refrigerant flowing through the bypass route (15); and

a control section (20) configured to control the bypass valve (16), wherein

the gas-liquid separator (14) includes an oil returning mechanism (142) configured to recover refrigerating machine oil accumulated inside in a state of being dissolved in a liquid phase of the refrigerant and to return the recovered refrigerating machine oil to the compressor (11), two-layer separation temperature on a low-temperature side of a mixed solution of the liquid phase of the refrigerant and the refrigerating machine oil is lower than a lower limit of prescribed evaporation temperature determined for the refrigeration unit, and

the control section (20) is configured to control the bypass valve (16) based on a predetermined condition under which deterioration of an oil returning property due to viscosity increase of the refrigerating machine oil is expected, to take bypass measures of opening the bypass route (15) or increasing the flow rate of the refrigerant flowing through the bypass route (15).

2. The refrigeration unit according to claim 1, wherein an index used for the condition is saturation temperature corresponding to pressure of the refrigerant that is sucked into the compressor (11), and the control section (20) is configured to control the bypass valve (16) to take the bypass measures in a case where the saturation temperature is lower than a prescribed value.
3. The refrigeration unit according to claim 1 or 2, wherein the control section (20) is configured to intermittently take the bypass measures every predetermined time based on the condition.
4. The refrigeration unit according to claim 2 or 3, wherein the control section (20) is configured to take the bypass measures in a case where saturation temperature corresponding to pressure of the refrigerant that is sucked into the compressor (11) is lower than a prescribed value and a liquid level of the refrigerating machine oil in the compressor (11) is lower than a prescribed liquid level.
5. The refrigeration unit according to claim 4, further including an oil level sensor (23) configured to detect the liquid level of the refrigerating machine oil in the compressor (11).
6. The refrigeration unit according to claim 5, wherein the oil level sensor (23) includes a first oil level switch

- (231) and the second oil level switch (232), the first oil level switch (231) being configured to detect that the oil level of the refrigerating machine oil accumulated in the compressor (11) is higher than a first level, the second oil level switch (232) being configured to detect that the oil level of the refrigerating machine oil accumulated in the compressor (11) is higher than a second level higher than the first level.
7. The refrigeration unit according to any one of claims 4 to 6, wherein the control section (20) is configured to control the bypass valve (16) to terminate the bypass measures when a prescribed time elapses after the start of the bypass measures, or when the liquid level of the refrigerating machine oil in the compressor (11) reaches at least the prescribed liquid level by the bypass measures.
 8. The refrigeration unit according to any one of claims 2 to 7, wherein the control section (20) is configured to take the bypass measures in a case where saturation temperature corresponding to pressure of the refrigerant that is sucked into the compressor (11) is lower than a prescribed value and a degree of superheat of the refrigerating machine oil in the compressor (11) is higher than a prescribed degree of superheat.
 9. The refrigeration unit according to claim 8, further including a temperature sensor (25) configured to detect a temperature of the refrigerating machine oil in the compressor (11), wherein the control section (20) is configured to calculate the degree of superheat of the refrigerating machine oil from a difference between the temperature of the refrigerating machine oil detected by the temperature sensor (25) and the saturation temperature.
 10. The refrigeration unit according to any one of claims 4 to 9, wherein the control section (20) is configured to control the bypass valve (16) to terminate the bypass measures when a prescribed time elapses after the start of the bypass measures, or when a degree of superheat of the refrigerating machine oil in the compressor (11) is suppressed to at least a prescribed degree of superheat by the bypass measures.
 11. The refrigeration unit according to any one of claims 2 to 10, further including a pressure sensor (21) configured to detect pressure of the refrigerant that is sucked into the compressor (11), wherein the control section (20) is configured to calculate the saturation temperature using the detected pressure.
 12. The refrigeration unit according to claim 11, wherein the pressure sensor (21) is installed on an inlet side of the gas-liquid separator (14).
 13. A refrigeration system that includes a compressor (11) configured to compress a refrigerant, a heat exchanger (12) configured to exchange heat of a refrigerant with air, a decompression section (13) configured to decompress the refrigerant, and an evaporator configured to evaporate the refrigerant, the refrigeration system comprising:
 - a gas-liquid separator (14) interposed between the evaporator and the compressor (11);
 - a bypass route (15) configured to cause at least a part of the refrigerant flowing toward the decompression section (13) through the heat exchanger (12), to flow into the gas-liquid separator (14);
 - a bypass valve (16) configured to open or close the bypass route (15), or to regulate a flow rate of the refrigerant flowing through the bypass route (15); and
 - a control section (20) configured to control the bypass valve (16), wherein the gas-liquid separator (14) includes an oil returning mechanism (142) configured to recover refrigerating machine oil accumulated inside in a state of being dissolved in a liquid phase of the refrigerant and to return the recovered refrigerating machine oil to the compressor (11), two-layer separation temperature on a low-temperature side of a mixed solution of the liquid phase of the refrigerant and the refrigerating machine oil is lower than a lower limit of prescribed evaporation temperature determined for the refrigeration system, and the control section (20) is configured to control the bypass valve (16) based on a predetermined condition under which deterioration of an oil returning property due to viscosity increase of the refrigerating machine oil is expected, to take bypass measures of opening the bypass route (15) or increasing the flow rate of the refrigerant flowing through the bypass route (15).
 14. A method of controlling a refrigerant circuit (10) that includes a compressor (11) compressing a refrigerant, a heat exchanger (12) exchanging heat of the refrigerant with air, and a decompression section (13) decompressing the refrigerant, the refrigerant circuit (10) including a gas-liquid separator (14), a bypass route (15), and a bypass valve (16), the gas-liquid separator (14) being interposed between a heat use destination (A) to which the refrigerant passed through the decompression section (13) is supplied and the compressor (11), the bypass route (15) causing at least a part of the refrigerant flowing toward the decompression section (13) through the heat exchanger (12), to flow into the gas-liquid separator (14), and the bypass valve (16) opening or closing the bypass route (15), or regulating a flow

rate of the refrigerant flowing through the bypass route (15), the method comprising:

controlling the bypass valve (16) to open the bypass route (15) or to increase the flow rate of the refrigerant flowing through the bypass route (15), based on a predetermined condition under which deterioration of an oil returning property due to viscosity increase of refrigerating machine oil is expected; and
causing an oil returning mechanism (142) provided in the gas-liquid separator (14) to recover the refrigerating machine oil accumulated, in a state of being dissolved in a liquid phase of the refrigerant, inside the gas-liquid separator (14), and to return the recovered refrigerating machine oil to the compressor (11) .

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FIG. 1

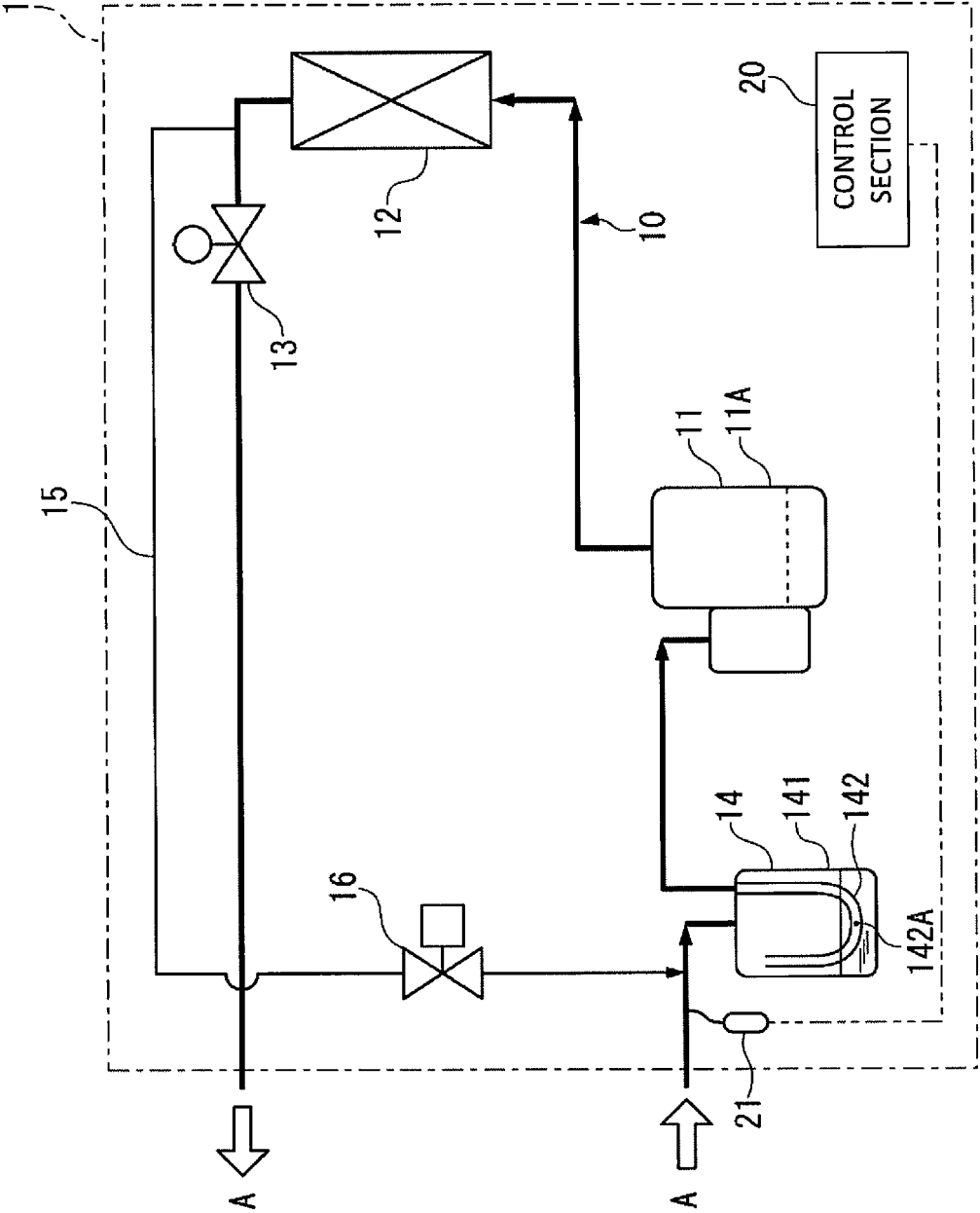


FIG. 2

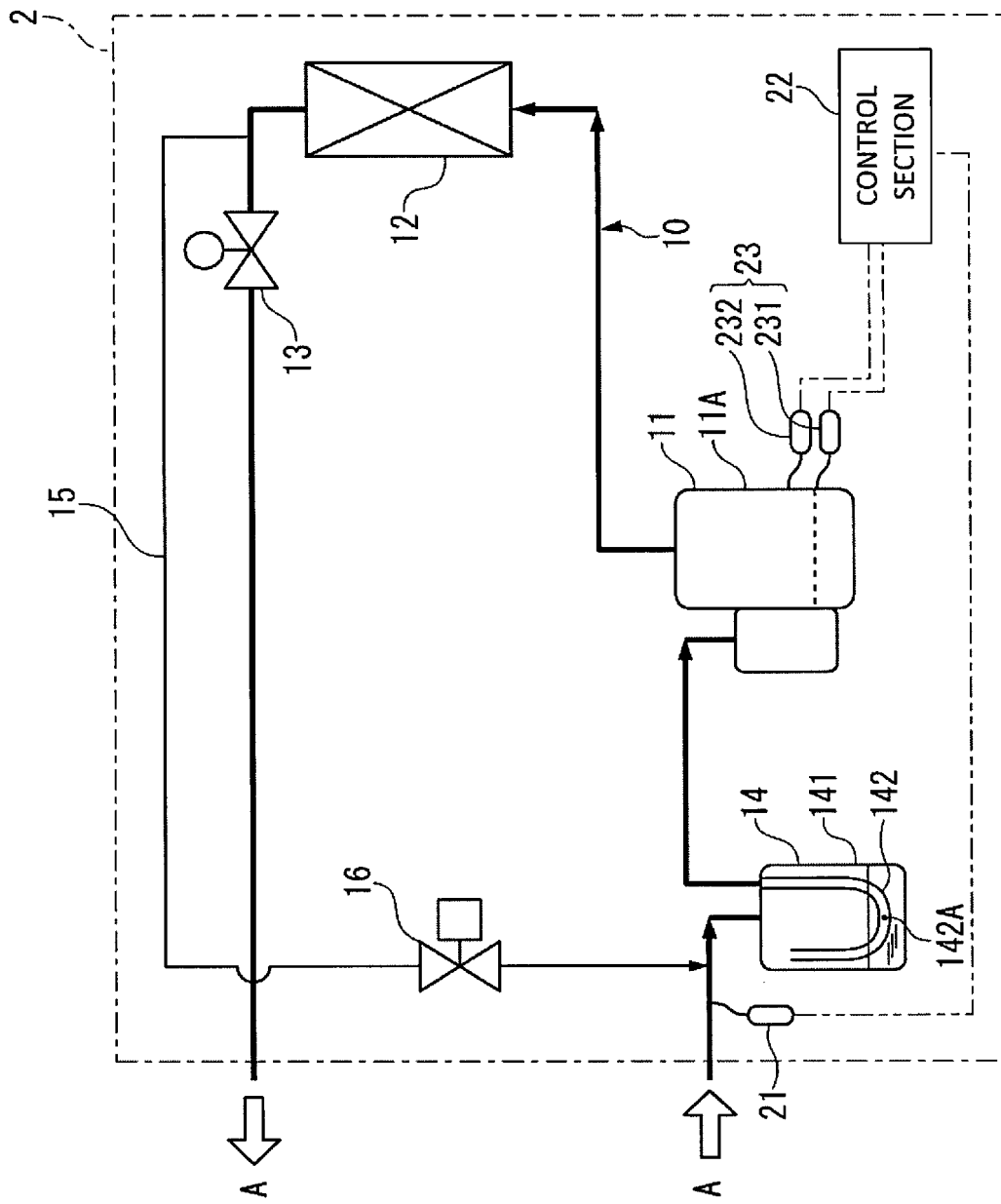
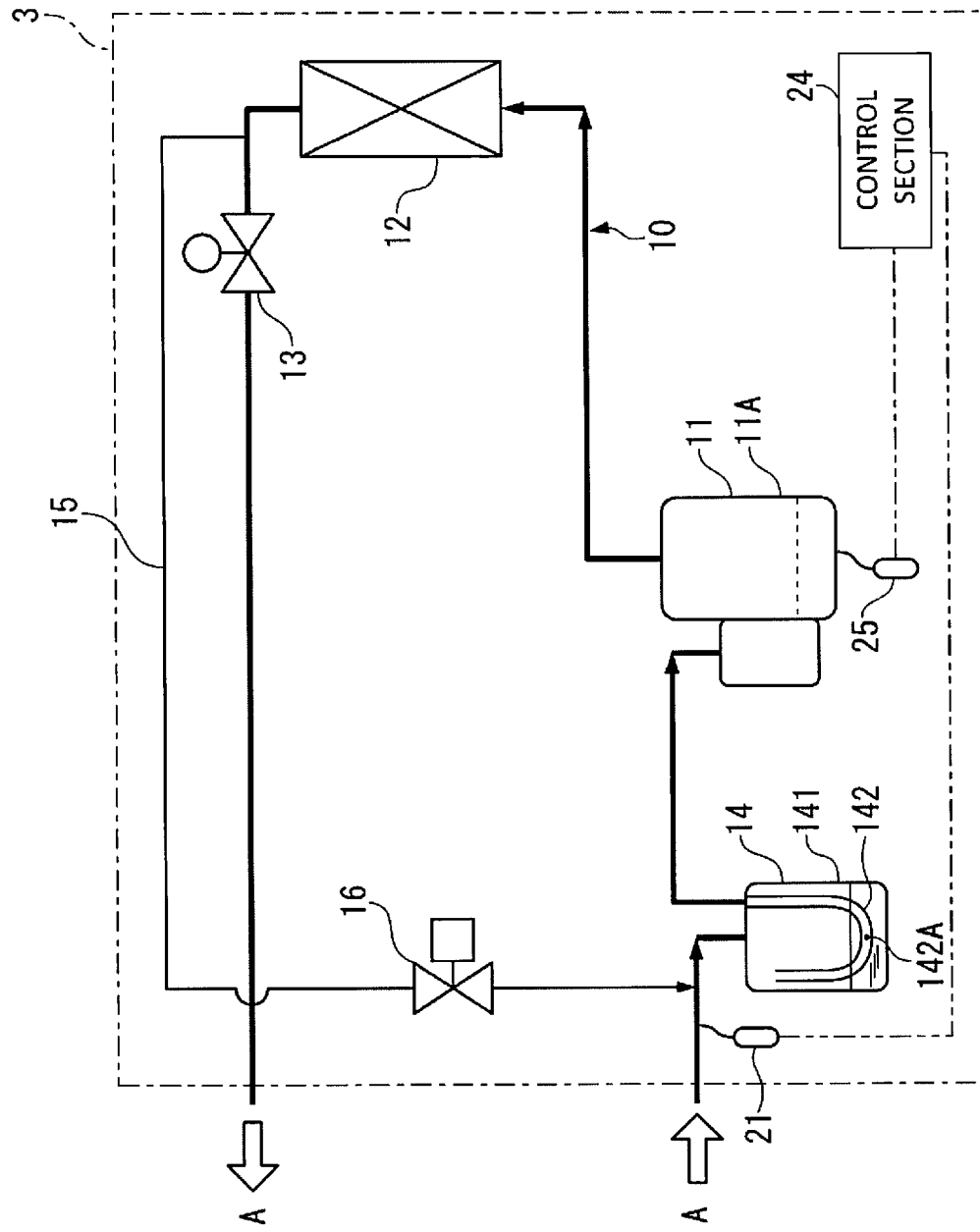


FIG. 3



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